METHOD FOR CONTROLLING OUTPUT OF A CLASSIFICATION ALGORITHM

CROSS-REFERENCE TO RELATED APPLICATION

This application claims priority under 35 U.S.C. §119(e) of U.S. provisional patent application Ser. No. 60/405,991 filed Aug. 26, 2002, the entire contents of which are incorporated by reference herein.

5 FIELD OF THE INVENTION

The present invention relates to the design, creation and use of an algorithm for controlling classification of a vehicle occupancy detection system.

BACKGROUND OF THE INVENTION

Vehicles currently include various systems whose operation depends on the occupancy of
10 the vehicle. For example, it has been known for some time that an occupant restraint or protection device can be designed to deploy differently depending on the type of occupants to be protected by the device (see for example, U.S. Pat. No. 5,829,782 (Breed et al.)). A classification of the occupancy of the vehicle is therefore desired in order to optimize the deployment of the occupant protection device.

15 Moreover, it is known that the position of the occupant can also affect the operation of various systems in the vehicle, most importantly, the occupant protection device (see, for example, U.S. Pat. No. 5,653,462 (Breed et al.)). Determination of the position of the occupant is therefore desired to optimize the deployment of the occupant protection device.

What is needed therefore is an algorithm which can optimize both the classification of the
20 occupancy of the vehicle and the determination of the position of the occupants.

Definitions:

Preferred embodiments of the invention are described below and unless specifically noted, it is the applicants' intention that the words and phrases in the specification and claims be given the ordinary and accustomed meaning to those of ordinary skill in the applicable art(s). If
25 the applicants intend any other meaning, they will specifically state they are applying a special meaning to a word or phrase.

Likewise, applicants' use of the word "function" here is not intended to indicate that the applicants seek to invoke the special provisions of 35 U.S.C. §112, sixth paragraph, to define their invention. To the contrary, if applicants wish to invoke the provisions of 35 U.S.C. §112,
30 sixth paragraph, to define their invention, they will specifically set forth in the claims the phrases

"means for" or "step for" and a function, without also reciting in that phrase any structure, material or act in support of the function. Moreover, even if applicants invoke the provisions of 35 U.S.C. §112, sixth paragraph, to define their invention, it is the applicants' intention that their inventions not be limited to the specific structure, material or acts that are described in the preferred embodiments herein. Rather, if applicants claim their inventions by specifically invoking the provisions of 35 U.S.C. §112, sixth paragraph, it is nonetheless their intention to cover and include any and all structure, materials or acts that perform the claimed function, along with any and all known or later developed equivalent structures, materials or acts for performing the claimed function.

"Pattern recognition" as used herein will generally mean any system which processes a signal that is generated by an object (e.g., representative of a pattern of returned or received impulses, waves or other physical property specific to and/or characteristic of and/or representative of that object) or is modified by interacting with an object, in order to determine to which one of a set of classes that the object belongs. Such a system might determine only that the object is or is not a member of one specified class, or it might attempt to assign the object to one of a larger set of specified classes, or find that it is not a member of any of the classes in the set. The signals processed are generally a series of electrical signals coming from transducers that are sensitive to acoustic (ultrasonic) or electromagnetic radiation (e.g., visible light, infrared radiation, capacitance or electric and/or magnetic fields), although other sources of information are frequently included. Pattern recognition systems generally involve the creation of a set of rules that permit the pattern to be recognized. These rules can be created by fuzzy logic systems, statistical correlations, or through sensor fusion methodologies as well as by trained pattern recognition systems such as neural networks, combination neural networks, cellular neural networks or support vector machines.

A trainable or a trained pattern recognition system as used herein generally means a pattern recognition system that is taught to recognize various patterns constituted within the signals by subjecting the system to a variety of examples. The most successful such system is the neural network used either singly or as a combination of neural networks. Thus, to generate the pattern recognition algorithm, test data is first obtained which constitutes a plurality of sets of returned waves, or wave patterns, or other information radiated or obtained from an object (or from the space in which the object will be situated in the passenger compartment, i.e., the space above the seat) and an indication of the identify of that object. A number of different objects are tested to obtain the unique patterns from each object. As such, the algorithm is generated, and stored in a computer processor, and which can later be applied to provide the identity of an object

based on the wave pattern being received during use by a receiver connected to the processor and other information. For the purposes here, the identity of an object sometimes applies to not only the object itself but also to its location and/or orientation in the passenger compartment. For example, a rear facing child seat is a different object than a forward facing child seat and an out-of-position adult can be a different object than a normally seated adult. Not all pattern recognition systems are trained systems and not all trained systems are neural networks. Other pattern recognition systems are based on fuzzy logic, sensor fusion, Kalman filters, correlation as well as linear and non-linear regression. Still other pattern recognition systems are hybrids of more than one system such as neural-fuzzy systems.

The use of pattern recognition, or more particularly how it is used, is important to the instant invention. In the above-cited prior art, except in that assigned to the current assignee, pattern recognition which is based on training, as exemplified through the use of neural networks, is not mentioned for use in monitoring the interior passenger compartment or exterior environments of the vehicle in all of the aspects of the invention disclosed herein. Thus, the methods used to adapt such systems to a vehicle are also not mentioned.

A pattern recognition algorithm will thus generally mean an algorithm applying or obtained using any type of pattern recognition system, e.g., a neural network, sensor fusion, fuzzy logic, etc.

To "identify" as used herein will generally mean to determine that the object belongs to a particular set or class. The class may be one containing, for example, all rear facing child seats, one containing all human occupants, or all human occupants not sitting in a rear facing child seat, or all humans in a certain height or weight range depending on the purpose of the system. In the case where a particular person is to be recognized, the set or class will contain only a single element, i.e., the person to be recognized.

To "ascertain the identity of" as used herein with reference to an object will generally mean to determine the type or nature of the object (obtain information as to what the object is), i.e., that the object is an adult, an occupied rear facing child seat, an occupied front facing child seat, an unoccupied rear facing child seat, an unoccupied front facing child seat, a child, a dog, a bag of groceries, a car, a truck, a tree, a pedestrian, a deer etc.

An "object" in a vehicle or an "occupying item" of a seat may be a living occupant such as a human or a dog, another living organism such as a plant, or an inanimate object such as a box or bag of groceries or an empty child seat.

A "rear seat" of a vehicle as used herein will generally mean any seat behind the front seat on which a driver sits. Thus, in minivans or other large vehicles where there are more than

3

two rows of seats, each row of seats behind the driver is considered a rear seat and thus there may be more than one "rear seat" in such vehicles. The space behind the front seat includes any number of such rear seats as well as any trunk spaces or other rear areas such as are present in station wagons.

5 An "optical image" will generally mean any type of image obtained using electromagnetic radiation including visual, infrared and radar radiation.

In the description herein on anticipatory sensing, the term "approaching" when used in connection with the mention of an object or vehicle approaching another will usually mean the relative motion of the object toward the vehicle having the anticipatory sensor system. Thus, in a 10 side impact with a tree, the tree will be considered as approaching the side of the vehicle and impacting the vehicle. In other words, the coordinate system used in general will be a coordinate system residing in the target vehicle. The "target" vehicle is the vehicle that is being impacted. This convention permits a general description to cover all of the cases such as where (i) a moving vehicle impacts into the side of a stationary vehicle, (ii) where both vehicles are moving when 15 they impact, or (iii) where a vehicle is moving sideways into a stationary vehicle, tree or wall.

"Out-of-position" as used for an occupant will generally mean that the occupant, either the driver or a passenger, is sufficiently close to an occupant protection apparatus (airbag) prior to deployment that he or she is likely to be more seriously injured by the deployment event itself than by the accident. It may also mean that the occupant is not positioned appropriately in order 20 to attain the beneficial, restraining effects of the deployment of the airbag. As for the occupant being too close to the airbag, this typically occurs when the occupant's head or chest is closer than some distance such as about 5 inches from the deployment door of the airbag module. The actual distance where airbag deployment should be suppressed depends on the design of the airbag module and is typically farther for the passenger airbag than for the driver airbag.

25 "Transducer" or "transceiver" as used herein will generally mean the combination of a transmitter and a receiver. In come cases, the same device will serve both as the transmitter and receiver while in others two separate devices adjacent to each other will be used. In some cases, a transmitter is not used and in such cases transducer will mean only a receiver. Transducers include, for example, capacitive, inductive, ultrasonic, electromagnetic (antenna, CCD, CMOS 30 arrays), electric field, weight measuring or sensing devices. In some cases, a transducer may comprise two parts such as the plates of a capacitor or the antennas of an electric field sensor. Sometimes, one antenna or plate will communicate with several other antennas or plates and thus for the purposes herein, a transducer will be broadly defined to refer, in most cases, to any one of

the plates of a capacitor or antennas of a field sensor and in some other cases a pair of such plates or antennas will comprise a transducer as determined by the context in which the term is used.

"Adaptation" as used here will generally represent the method by which a particular occupant sensing system is designed and arranged for a particular vehicle model. It includes such things as the process by which the number, kind and location of various transducers is determined. For pattern recognition systems, it includes the process by which the pattern recognition system is designed and then taught or made to recognize the desired patterns. In this connection, it will usually include (1) the method of training when training is used, (2) the makeup of the databases used, testing and validating the particular system, or, in the case of a neural network, the particular network architecture chosen, (3) the process by which environmental influences are incorporated into the system, and (4) any process for determining the pre-processing of the data or the post processing of the results of the pattern recognition system. The above list is illustrative and not exhaustive. Basically, adaptation includes all of the steps that are undertaken to adapt transducers and other sources of information to a particular vehicle to create the system that accurately identifies and/or determines the location of an occupant or other object in a vehicle.

For the purposes herein, a "neural network" is defined to include all such learning systems including cellular neural networks, support vector machines and other kernel-based learning systems and methods, cellular automata and all other pattern recognition methods and systems that learn. A "combination neural network" as used herein will generally apply to any combination of two or more neural networks as most broadly defined that are either connected together or that analyze all or a portion of the input data.

A "morphological characteristic" will generally mean any measurable property of a human such as height, weight, leg or arm length, head diameter, skin color or pattern, blood vessel pattern, voice pattern, finger prints, iris patterns, etc.

A "wave sensor" or "wave transducer" is generally any device which senses either ultrasonic or electromagnetic waves. An electromagnetic wave sensor, for example, includes devices that sense any portion of the electromagnetic spectrum from ultraviolet down to a few hertz. The most commonly used kinds of electromagnetic wave sensors include CCD and CMOS arrays for sensing visible and/or infrared waves, millimeter wave and microwave radar, and capacitive or electric and/or magnetic field monitoring sensors that rely on the dielectric constant of the object occupying a space but also rely on the time variation of the field, expressed by waves as defined below, to determine a change in state.

A "CCD" will be defined to include all devices, including CMOS arrays, APS arrays, QWIP arrays or equivalent, artificial retinas and particularly HDRC arrays, which are capable of converting light frequencies, including infrared, visible and ultraviolet, into electrical signals. The particular CCD array used for many of the applications disclosed herein is implemented on a

5   single chip that is less than two centimeters on a side. Data from the CCD array is digitized and sent serially to an electronic circuit (at times designated 120 herein) containing a microprocessor for analysis of the digitized data. In order to minimize the amount of data that needs to be stored, initial processing of the image data takes place as it is being received from the CCD array, as discussed in more detail above. In some cases, some image processing can take place on the chip

10   such as described in the Kage et al. artificial retina article referenced above.

The "windshield header" as used herein includes the space above the front windshield including the first few inches of the roof.

A "sensor" as used herein is the combination of two transducers (a transmitter and a receiver) or one transducer which can both transmit and receive. The headliner is the trim which

15   provides the interior surface to the roof of the vehicle and the A-pillar is the roof-supporting member which is on either side of the windshield and on which the front doors are hinged.

An "occupant protection apparatus" is any device, apparatus, system or component which is actuatable or deployable or includes a component which is actuatable or deployable for the purpose of attempting to reduce injury to the occupant in the event of a crash, rollover or other

20   potential injurious event involving a vehicle.

With respect to the classification of objects, an "empty seat" determination can also be classified as "restraint system disable" (since the restraint system would typically be disabled for an empty seat) although the presence of a child seat can also result in a disabled restraint system (i.e., a classification of "restraint system disable"). Thus, when the classification of an "empty

25   seat" is used below, it will also mean "restraint system disable" except where the context indicates otherwise.

OBJECTS AND SUMMARY OF THE INVENTION

It is an object of the present invention to provide a new and improved algorithm capable of providing information on occupancy of a vehicle.

30   It is another object of the present invention to provide a new and improved algorithm that provides information on vehicle occupancy with the occupants being classified separately from a determination of the occupant's position so that each task can be optimized independent of the other task.

6

It is yet another object of the present invention to provide a new classification system and method that requires increased evidence to change a classification when the time of the previous classification is increased.

Another object of the present invention is to provide a new classification system where the length of time that one classification occurs affects the length of time before the classification is permitted to change.

Yet another object of the present invention is to provide a new system to reduce toggling between classification states by requiring a minimum amount of time to pass where the new classification state occurs before changing the output of the classification system.

Still another object of the present invention is to provide a time-based classification system which is reset upon the occurrence of an event selected from the group of empty seat, door opening, vehicle ignition, vehicle motion and lack of vehicle motion.

In order to achieve at least one of these objects, a method for controlling output of a classification algorithm which classifies an occupant of a seat comprises the steps of initially classifying the occupant and outputting the classification, subsequently periodically classifying the occupant and enabling a change in the classification of the occupant only upon obtaining evidence of a new classification which is greater than evidence of the current classification. One time-based way in which greater evidence of a new classification than the current classification is established is by determining a consecutive period of time that the classification of the occupant is the same as the output classification, detecting a change in classification and then determining a consecutive period of time that the classification of the occupant is the changed classification, and when the period of time in which the classification is the changed classification is greater than the period of time when the classification is the output classification, outputting the changed classification.

The initial classification of the occupant may be conducted based on satisfaction of a condition such as the detection of closure of a door by, e.g., a sensor such as a door closed sensor, the detection of an empty seat by, e.g., an occupant presence sensor, weight sensor, camera and the like, and the detection of the switching on of the vehicle ignition by an appropriate sensor.

Optionally, a determination is made whether the period of time that the classification of the occupant is the same as the output classification. is greater than a pre-determined time threshold. If so, the period of time that the classification of the occupant is the same as the output classification is set to the pre-determined threshold. This provides an upper limit the amount of time needed to effect a change in the output classification.

7

The classification of the occupant can be performed using a trained neural network such as a modular neural network, a combination neural network, and the like.

Data may be obtained from sensors such that the classification of the occupant is performed using the data obtained from the sensors. For example, data from at least one camera may be used such that the classification of the occupant is performed using the data obtained from the camera(s). The sensors may be any type which provides a signal dependent on the occupancy of the seat including, but not limited to, a weight sensor, a capacitance-based sensor, an electric field-based sensor, a radar or other electromagnetic wave-based sensor, a camera-based sensor including a 3D sensor, and an ultrasonic-based sensor. Combinations of these sensors can be used.

With respect to the classification task, once the door of the vehicle is closed, it is difficult, but not impossible, to change the occupancy of the front passenger seat, for example. On the other hand, whatever is occupying the front seat, it is possible for that occupant to take a position that fools the system, i.e., causes the system to determine a classification of the occupant that differs from the actual classification of the occupant. An adult, for example, can be in a pose that makes the system think that it is an empty seat or a child seat, or a 5% female can look like a child for some poses. On the other hand, it is difficult and unlikely that in either case that the occupant will be able to stay in that deceptive pose for very long. Thus, if the majority of the time the occupant looks like an adult, then there is no reason to change the decision even if the system momentarily thinks that the occupant is a child seat.

One-way of taking advantage of this situation is to base a new decision for the algorithm, i.e., cause the algorithm to provide an output to be acted upon, on some event such as the closing of the vehicle door. This would constitute a conditional determination by the algorithm as it would not continually provide new decisions on the classification of the occupant but would only do so when certain conditions are satisfied.

Thus, when the vehicle door is closed the system will determine the seat occupancy classification and gradually increase its confidence as more and more data sets give the same answer. For the decision to be changed would require that a similar amount of data gave a new decision. For example, let us say that the system classified the occupant as an adult for 1000 shots (about 300 seconds or 5 minutes for a slow system). To change that decision to a child seat might require a similar amount of data or 1000 shots. On the other hand, if only 10 shots came up with an adult decision followed by 11 for the child seat, the decision would be changed. The system would start over from the beginning every time it sensed an empty seat, that the door was opened, the ignition turned on or initial vehicle motion was sensed after a period of no motion. In

8

the latter example, if the vehicle has not moved for some period of time, such as 10 minutes, then the classification system can be reset. Any one of more of these events can be used as well as a variety of other events as desired by the automobile manufacturer.

Another method for controlling output of a classification algorithm which classifies an occupant of a seat comprises the steps of setting the output classification to an empty seat, subsequently classifying any occupant of the seat, determining whether the classification is other than an empty seat and if not, periodically repeating the step, otherwise, when the classification is other than an empty seat, repeating the classification step, if the repeated classification step provides a classification of an empty seat, setting the output classification to an empty seat, if the repeated classification step provides a stable classification, then setting the output classification to the stable classification, repeating the classification step, and changing the classification only when the repeated classification step provides a classification of an empty seat in which case, the classification is changed to an empty seat.

The repeated classification steps provide a stable classification when the classification is the same for a pre-determined period of time. The classification of the occupant may be performed using a trained neural network or other pattern recognition system or even, in the case of a bladder, strain gage or other weight sensor, a simple calculation.

Accordingly, the invention restricts changes between different classification decisions by a classification algorithm, such as changes between adult decisions and child/child-seat decisions, and moreover, uses certain time-based references as reset points to allow changes in the classification decision.

In more general terms, the longer that the decision stays with a particular classification, the more difficult it is to change the classification unless some event happens such as the sensing of an empty seat, the turning on of the ignition or the opening of the door. With an optical system and using modular networks, a special network can be trained to recognize an open door, for example, or an empty seat.

Another method for controlling output of a classification algorithm which classifies an occupant of a seat entails initially classifying the occupant and outputting a current classification, subsequently periodically re-classifying the occupant, determining a consecutive period of time when the re-classification of the occupant is unchanged and different from the current classification and enabling a change in the classification of the occupant only upon when the consecutive period of time is greater than a threshold and then outputting the changed classification. The same enhancements in the above-described method can be applied in this method as well.

9

Still another method for controlling output of a classification algorithm which classifies an occupant of a seat in a vehicle entails initially classifying the occupant and outputting a current classification, subsequently periodically re-classifying the occupant, enabling a change in the classification of the occupant upon satisfying pre-determined criteria, resetting the classification upon detection of a condition selected from a group consisting of an empty seat, opening of a door, ignition of the vehicle, motion of the vehicle and absence of motion of the vehicle and then, upon resetting of the classification, classifying the occupant and outputting the classification. The same enhancements in the above-described method can be applied in this method as well.

For example, a change in the classification of the occupant may be enabled by determining a consecutive period of time that the re-classification of the occupant is the same as the current classification, detecting a change in classification and then determining a consecutive period of time that the re-classification of the occupant is the changed classification and when the period of time in which the classification is the changed classification is greater than the period of time when the classification is the output classification, or greater than a predetermined time period, outputting the changed classification. In the alternative, a change in the classification of the occupant may be enabled by determining whether the period of time that the re-classification of the occupant is the same as the current classification is greater than a pre-determined time threshold and if so, setting the period of time that the classification of the occupant is the same as the current classification to the pre-determined threshold.

Still another method for controlling output of a classification algorithm which classifies an occupant of a seat entails setting the output classification to an empty seat, subsequently classifying any occupant of the seat, and determining whether the classification is other than an empty seat and if not, periodically repeating the step, but otherwise, when the classification is other than an empty seat, repeating the classification step. If the repeated classification step provides a classification of an empty seat, the algorithm entails setting the output classification to an empty seat and if the repeated classification step provides a stable classification, then the output classification is set to the stable classification. The classification step is repeated and the classification is changed only when the repeated classification step provides a classification of an empty seat in which case, the classifications changed to an empty seat.

Another method for controlling classification of an occupant of a seat entails providing an empty-seat state in which a stored classification is set to an empty seat, subsequently classifying occupancy of the seat and when the classification is other than an empty seat, exiting the empty-seat state and setting the algorithm in a transition state and storing the non-empty seat classification, periodically reclassifying occupancy of the seat and changing the stored

10

classification to the re-classified occupancy when the re-classified occupancy is different than the stored classification, determining whether the stored classification satisfies a first condition and if so, exiting the transition state and setting the algorithm in a revoking state, determining whether the stored classification satisfies a second condition different than the first condition and if so,

5   exiting the revoking state and setting the algorithm in a classified state, and when the algorithm is in the classified state, outputting the stored classification.

In some enhanced embodiments, when the algorithm is in the classified state, the occupancy of the seat is re-classified and a change in the stored classification is prevented entirely or allowed only if the re-classified occupancy satisfies a third condition which may be a time-based condition more onerous that the second condition and the second condition is a time-based condition more onerous than the first condition.

BRIEF DESCRIPTION OF THE DRAWINGS

The following drawings are illustrative of embodiments of the invention and are not meant to limit the scope of the invention as encompassed by the claims.

10   FIG. 1 is a flow chart of the manner in which one embodiment of the algorithm in accordance with the invention operates.

FIG. 2 is a flow chart showing the manner in which another embodiment of the algorithm in accordance with the invention operates.

FIG. 3 is a flow chart showing the manner in which another embodiment of the algorithm

15   in accordance with the invention operates.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

Referring to the accompanying drawings wherein the same reference numerals refer to the same or similar elements, FIG. 1 shows an algorithm for controlling changes in a classification process performed by a system in a vehicle which requires that the occupants of the

20   vehicle be classified.

This algorithm functions based on the satisfaction of a condition such as closure of a door as represented at 10. When closure of the door is detected, a data set is obtained from sensors used in the classification process at 12 and the seat occupancy is determined at 14. A variable n is set to 1 at 16, this variable will be used to count the number of times the seat occupancy is

25   classified the same. A new data set is obtained from the sensors at 18 and the seat occupancy is determined at 20. A determination is made whether the new classification is the same as the immediately previous classification at 22. If so, the variable n is increased by 1 at 24 and a new data set is obtained from the sensors at 18 and the seat occupancy is determined from the new

11

data set at 20. Thus, the variable n will represent the number of times that data sets provide the same seat occupancy classification.

Sensors at 18 may be any type of occupant sensors including but not limited to all types of weight sensors, capacitance based sensors, electric field based sensors, radar or any other electromagnetic wave or electric field based sensors, camera based sensors including 3D sensors, ultrasonic based sensors, etc.

If the new classification is not the same as the old classification, then a variable m is set to 1 at 26. As shown at 28, the new classification is not output to components whose operation or function depends on the classification as the new classification might be erroneous, i.e., there may not be any change in occupancy of the seat but rather, the occupant may have moved. A new data set is obtained from the sensors at 30 and the seat occupancy is determined at 32. A determination is made whether the classification is the same as the immediately previous classification at 34. If so, the variable m is increased by 1 at 36. The variable m will thus represent the number of times that the data sets provided the same seat occupancy classification for the new classification.

At step 38, a determination is now made as to whether the number of times the new classification is output is greater than the number of times the previous classification was output, i.e., whether m is greater than n. If not, the new classification is not output and a new data set is obtained at 30, seat occupancy is determined at 32 from the new data set and the process continues.

When m is greater than n, it signifies that the new classification is provided by data sets more times than the previous classification, i.e., evidence of the new classification is greater than evidence of the previous classification. This is used to concretely establish a change in classification so that the new classification is output to the components and system which vary their function or operation based on the classification of the occupants (step 40). At step 42, this new classification will be used as the base classification (by setting n equal to m) and different classifications will be compared to this new classification.

Variations in this algorithm can be used to limit the time required for a change in classification, for example, by putting a maximum value on n and when this maximum value is reached, any attempt to increase n would instead result in m being decreased by 1 until m is zero. Naturally, many other algorithms can be used to accomplish this same goal of making a change of classification difficult within certain time limits. Thus, a change of classification may be permitted whenever a new classification is detected consistently for 3 minutes, for example.

It is also possible to adjust n as a function of m or vice versa, i.e., as m (the duration of the new classification) increases, n (the duration of the previous classification) could decrease.

12

This would accelerate changes in the classification and prevent the possibility of never allowing a change in the classification. Thus, the length of time that one classification occurs would affect the time required to allow the classification to change.

For example, if the old classification lasted for 16 minutes (n=96 with a classification occurring every 10 seconds), and a new classification last for 10 seconds (m=1), the system might not change. However, as the new classification lasts for 1 minute (m=6) and then 2 minutes (m=12), n could be decreases as the probability of the new classification being accurate increases. Thus, n could be 96 for the first minute after a change in classification and then decrease by 50% for each subsequent minute after the change in classification (n=48 in the second minute, n=24 in the third minute and n=12 in the fourth minute). As such, m would be greater than n in the fourth minute and the classification would change after only three minutes.

Referring now to FIG. 2, in this embodiment, the algorithm does not rely on the opening and/or closing of a door. Instead, it relies on the detection of the empty seat (whether the door is opened or not). The reason is that, because of possible configuration of camera used in the classification process, it is easier to detect an empty seat than to detect an open door. On the other hand, if the system has a door closed signal input, then it would be quite easy to detect the opening and closing movements of the door.

The logic algorithm shown in FIG. 2 is added onto and is not a replacement for the feature extraction algorithm and the modular neural network algorithm. As already known, it is difficult is not impossible to make the success rate of the feature extraction algorithm and the modular neural network algorithm to be absolute 100%. There will always be weak spots or "holes". The purpose of this algorithm is to minimize the effect of these isolated weak spots. It is recommended that the neural network decisions should be filtered to remove any random noise before this algorithm is applied.

The time when the classification system is running can be considered as a sequence of 3 types of states: empty-seat state, transition state and a classified or classification state. The empty-seat state is a time period when the system decides that the passenger seat is empty. The classification state is a time period when the system decides whether the passenger seat is occupied by an adult or a child/child-seat. From an empty-seat state to a classification state, the system must pass a transition state.

The system starts or re-starts from an empty-seat state at step 44. The empty-seat state can be detected by various sensors, including one or more weight sensors arranged in connection with the seat, an electric field sensor arranged to create an electric field through the occupancy area of the seat such that the presence of an object in the seat changes the electric field sensed by

the electric field sensor, or a wave-receiving sensor which receives waves from the area of occupancy of the seat.

When the decision algorithm changes at step 46, it goes into a transition state at step 48. The transition state continues until the decision made at step 50 either changes back to an empty-seat or becomes stable. If the decision changes back to empty-seat, the system goes back to an empty-seat state. If the decision becomes stable at 52, the system goes into a classification state at step 54. Once the system is in a classification state, it remains in the classification state until the decision algorithm changes to indicate an empty-seat at step 56. Then the system goes back to an empty-seat state.

An important aspect of the algorithm is that the occupancy state changes between adult and child/child-seat must be more restricted in the classification states than in the transition states.

It is necessary to have a transition state when the occupancy state changes between adult and child/child-seat which is less restricted. When an adult or a child gets into the passenger seat, it is very likely that he/she will move around doing things like adjusting the seat position, applying the seatbelt, or just putting objects in place. When people put a child seat or an infant carrier into the passenger seat, it is very likely that people will lean over to adjust the seat position, apply the restraining system such as a seatbelt, adjust the handle or shade, or just check if the baby is comfortable. During that period of time, the image pattern is very complicated and it is very difficult to train neural networks, for example, to handle all such cases. The system will toggle between classification decisions. After a while, the decisions of the algorithm will become stable. If the decisions remain constant without toggling for a certain period of time such as 10 seconds (or 5 minutes as specified by the customer), the system goes into a classification state.

Once the system is in a classification state, the occupancy state changes between adult and child/child-seat is much more restricted. This can be implemented using a filtering mechanism with long delay time.

This second embodiment overcomes some of the drawbacks of the first algorithm described above with reference to FIG. 1. Specifically, possible issues with the algorithm shown in FIG. 1 are that when the occupant moves close to a "hole", the output of the decision algorithm becomes weak and close to the threshold. As result, the decision changes back and forth. So within a short amount of time, there will be similar numbers of decisions at both classifications, and one or two new decisions can easily trigger a decision change. Further, it is difficult for the system to recover from a "hole" in that if the occupant stays in a "hole" for a very long time, it can take an equally long time for the decision to be corrected after the occupant changes back to a normal position, depending on the particular algorithm implemented. For example, if the

14

passenger has been asleep with their feet on the instrument panel, or have a blanket covering their legs, and newspapers on the blanket for one hour, and that has been interpreted as a child seat by the system, after he/she wakes and sits up, it could take another hour for the airbag to be re-enabled depending on the particular algorithm implementation.

It is also possible to use a fixed long time period. In this case, if the decision of the decision algorithm (which is conflicting with the current classification) lasts for more than 5 to 15 minutes, for example, without toggling, the system can change the decision.

Referring now to FIG. 3, in some embodiments, the time when the classification system is running can be considered as a sequence of 4 different types of states or periods: an empty-seat state 60, a transition state 62, a revoking state 64 and a classified or classification state 66. The empty-seat state 60 is a time period when the system decides that the passenger seat is empty and unoccupied (in any of the ways described above). The classification state 66 is a time period when the system decides whether the passenger seat is occupied by an adult or a child/child-seat (in any of the ways described above). From the empty-seat state 60 to the classification state 66, the system must pass both the transition state 62 and the revoking state 64. These states have the following definitions:

1. Empty-Seat State 60 ---- Any empty-seat decision resets the system, and the system goes into the empty-seat state 60. The system or algorithm starts from the empty-seat state 60 and returns to the empty-seat state 60 every time the incoming classification is determined to be an empty-seat.

2. Transition State 62 ---- From the empty-seat state 60, any non empty-seat decision moves the system into the transition state 62 (along the path designated 1). During the transition state 62, the system is allowed to change between any non empty-seat classifications freely. The classification obtained each time the system performs a classification is stored in a memory so that the stored classification changes freely every time the occupancy is re-classified and is different than the immediately preceding classification.

3. Revoking State 64 ---- If the system keeps one decision (without toggling) in the transition state 62 for more than certain amount of time (or upon satisfaction of another condition not necessarily based on time, e.g., buckling of the seatbelt), the system goes into the revoking state 64 (along the path designated 2). During the revoking state 64, the system is allowed to change between any non empty-seat classifications only if the non-toggling occurrence of the new classification exceeds the non-toggling occurrence of the previous, stored classification (or evidence of the new classification is greater than

evidence of the previous classification which is not required to be a time-based condition). The non-toggling occurrence of the previous, stored classification may be a consecutive length of time in which the classification is the same. If the non-toggling occurrence of the new classification is an empty-seat decision and it exceeds the non-toggling occurrence of the previous classification (or evidence of the empty-seat is greater than evidence of the previous classification which is not required to be a time-based condition), then the system changes to the empty-seat state 60 (along the path designated 3). From the revoking state 64, the system can change the stored classification to the empty-seat state 60 upon occurrence of an event, such as a change in weight applied of the seat, a determination of an empty seat by an occupant presence sensor and the like.

4. Classified State 66 ---- If the system keeps one classification decision (without toggling) in the revoking state 64 for more than certain amount of time, the system goes into the classified state 66 (along the path designated 4) and outputs the stored classification, e.g., for use in vehicular systems. During the classified state 66, either the system is not allowed to change between any non empty-seat classifications at all, or the system is allowed to change only if the non-toggling occurrence of the new classification exceeds a large threshold. From the classified state 66, the system can change to the empty-seat state 60 upon occurrence of an event, such as a change in weight applied of the seat, a determination of an empty seat by an occupant presence sensor and the like.

A classification algorithm can thus be designed to provide the four different states and allow movement between the states as follows:

movement along path 1, from the empty-seat state 60 to the transition state 62, if the incoming classification is not an empty-seat;

movement along path 1, from the transition state 62 to the empty-seat state 60, if the incoming classification becomes empty-seat;

movement along path 2, from the transition state 62 to the revoking state 64, if the incoming classification satisfies a first condition, such as lasting more than a certain amount of time (T_1) without toggling;

movement along path 3, from the revoking state 64 to the empty-seat state 60, if the incoming classification becomes an empty-seat;

movement along path 4, from the revoking state 64 to the classified state 66, if the incoming classification satisfies a second condition, such as lasting more than a certain amount of time (T_2) without toggling (typically $T_2 >> T_1$); and

movement along path 5, from the classified state 66 to the empty-seat state 60, if the incoming classification becomes an empty-seat.

Change within the classified state 66 may be allowed only if the classification satisfies a third condition which is more onerous than the second condition, which in turn is more onerous than the first condition.

Thus, in comparison to the algorithm applying the method in FIG. 2, in an algorithm applying the method shown in FIG, 3, an additional state is provided in which changes in the classification are less restricted than in the classification state. In accordance with the invention, it is possible to introduce multiple states with varying degrees of permissibility in the changes in the classification. The permissibility for changes in the classification in each state might be time-based or based on other conditions.

Many changes, modifications, variations and other uses and applications of the subject invention will, now, become apparent to those skilled in the art after considering this specification and the accompanying drawings which disclose the preferred embodiments thereof. All such changes, modifications, variations and other uses and applications which do not depart from the spirit and scope of the invention are deemed to be covered by the invention which is limited only by the following claims.